It's All In The Acoustic Details

Part I

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Reader Caution: *The following series is about acoustics. Many consider the topic scary, unsexy, and elusive. Many more never even consider the topic. If you care more about how your theatre looks when the lights are on, than how hard your blood is pumping when the movie is on, you may skip this series and proceed to Dullsville.*

Trying To Race On Bald Tires

You've been saving up for years and now you're picking up your dream car from a private party out of state. It's used, but it's a blue Ferrari and the previous owner has had it tuned up for you by the dealer. You start her up and she purrs beautifully. As you rev her up, she growls that classic Ferrari sound you have coveted for so long. On the way home you notice that she is a bit squirrelly. You toss it up as more power under the hood than you're used to. Then it begins to rain and with the slick roads she is hydroplaning heavily. This is not what you anticipated. You now realize that the car has the potential, but it is all resting on bald tires. It's out of control. Your investment is not as sweet as you first thought and is going to cost you more dollars before you can experience what you expected.

I've used the above analogy over the years to describe the important role acoustics plays in regards to playback equipment performance. It is the foundation. Great equipment cannot sound great in a poor environment. Conversely, moderately good equipment, set up properly in a good environment, will outperform 90 percent of the high-end systems you see in magazines. Good set-up equals good performance, which results in a good experience. Just as the contact between tires and road relates to the driving experience of a sports car, so does acoustics relate to the audio experience of your electronics. If you want your equipment to perform optimally, your investment to really pay off, and experience what the artist intended, it is imperative that the acoustics be controlled. This series will delve into the importance of acoustics and how it drives the outcome of your experience. We will discuss numerous myths, common errors, some of my many personal rants, and back them up with science in layman terms. We will reveal an audio playback hierarchy and how it relates to psychoacoustics. And finally, we will prove to the court that acoustics takes precedence over equipment quality. Yes, regardless of the cost of your audio system, you will learn how it could be made to sound better and to look into acoustics before equipment upgrades. Acoustics, as it relates in this series of articles, will include the entire electro-acoustical system, including: equipment positioning, equipment calibration, interior acoustic treatments, as well as power quality and noise control. There are many acoustic issues that you can tackle yourself and there are many that should be handled by a specialist. It is my hope that you will become more keenly aware of acoustical distortions, what causes them and where to turn to resolve them. It is my experience that all most everybody out there is trying to race on bald tires.

Rant: *Most of the consumer electronic population does not understand what a good experience is in the first place.*

It used to be that you could walk into a stereo store and be treated to a quality audio demonstration behind closed doors, and what we heard influenced our purchases. Those of us who have experienced good demos have stored in our neural pathways of long-term memory, developed impressions that allow us to form opinions. We may use descriptors such as: fast, articulate, dynamic, wide soundstage, smooth highs, deep bass, etc. to help communicate aural characteristics that are important to us. Our personal exposures dictate what we recognize as "good sound," right or wrong. Our influence may have been that of an older brother's system, a friend of dad's, or the local stereo store. Whatever we consider the best we've heard in our minds is all we know and becomes our current reference. Specialty stores, as they are referred to today, are an endangered species. Today's generation has not had the chance to learn from good demos. In general, all they "know" is listening to MP3 audio through ear buds while multi-tasking. This is their experience. The sonic descriptors previously mentioned hardly apply to such low level audio quality.

As with our own musical development during infancy we learn to like simple tunes, but as we mature, and are exposed to more complex arrangements, rhythms and instrumentation, we become bored with such basic forms of expression. The same holds true with audio and just about any other subject; you start out with a small taste and if you like it, you expand on it. Imagine listening to a Mozart melody on a child's electronic toy, only hearing one note at a time and at one loudness level. It may still sound pretty, but pretty lifeless. Now imagine listening to the actual score as performed by a full orchestra in a concert hall. Timbres, reverberations, meters, dynamics, tactile elements, etc. come to play with your emotions. The music is conveyed to you at a much higher level. Though it's the same tune, it becomes more interesting because there is so much more going on to grab your attention. Now imagine listening to the same performance compressed to MP3 and played back over ear buds. Much of the information eludes us due to the simplicity of the elected audio system and we are left less satisfied.

Now think about your existing system. You may think it's all there and sounds great, but unless you have actually "heard it all," you can't know the difference or what you are missing.

Should you care, if you are content with what you have? Maybe not, but at least know that there is more to be had if you are interested. Have you experienced chills run down your spine, hairs stand on end or tears well up in your eyes because of beautiful sound? Do you ever feel an adrenaline rush just sitting there enjoying a movie, or jump at a startling noise? If you have not had such connections to music or movie playback, you are either not that interested or have not been exposed to it yet. When details are lost in texture, dynamic range, spatial cues, etc., we experience less interest and involvement, and therefore, less

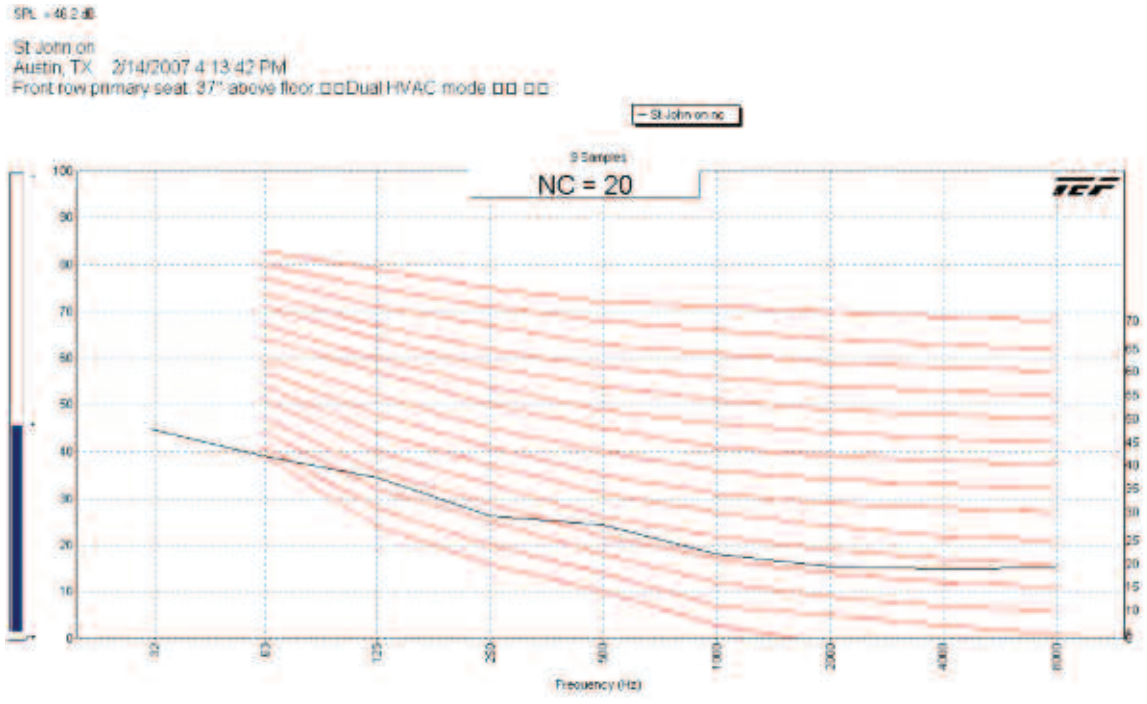

Figure 1

emotional connection and impact is made. Specifically, fewer neuron connections are formed in the auditory cortex and less action occurs in the Hippocampus (auditory memories, experiences and coherence), Cerebellum (physical reactions to music such as dancing, foot tapping, playing an instrument) and the Amygdala & Nucleus Accumbens (emotional reactions to audio stimuli). Understand that your library of movies, CDs and concert videos are sitting there ready to unleash their magic for you, but the conditions have to be right and you are the one holding the cards.

Think: *Can you expect to have such an experience at the local big box store? Why not?*

Requirements For Good Sound

I have explained that there is much more to experience from your collection of recordings than you currently realize. Let's begin to talk about what is needed to obtain it. Please forgive me for relating acoustics to video calibration, but people seem to understand and accept video calibration much more than acoustics. As in video, each control likely influences others.

Black Level (Signal-To-Noise Ratio)

Before we can have sound quality, we must have noise control in place. In video, a good picture starts out black and has good contrast between light and dark images. This dynamic range or contrast ratio is determined by measuring the light emitted (typically lumen units) from the brightest output the system can produce before distortion and dividing by the darkest. If we have poor contrast from our display device, we will miss picture information that may be interesting to the eye, or important to the story. The same applies to audio. We must start out with silence. We must eliminate sounds that will distract us from our "zone" or mask resolution. There are many things that may be obstacles in the way of a low noise floor. For example: outside traffic, footfalls, air handling systems, equipment fans, motors, power line noise, equipment noise, etc. Silence, especially in movies, is used to get our attention and increase suspense.

Resolution (Dynamic Range)

Without a quiet background, low-level details are masked by noises of the environment, and interesting sounds and clues important to the story will be missed. The noise floor's dynamic range actually relies on two separate systems; one is the electrical system, and within the electrical system there is both the power source (the AC power line) as well as the A/V playback equipment. Both of these noise floors are defined as the signal-to-noise (S/N) ratio. Simplified, S/N is the measurement of a reference voltage signal strength to that of the thermal background noise level, typically converted and expressed in dB. There are many limiting factors on the recording side, including the S/N ratios introduced by electronic instruments, microphones, recording equipment and venue, but here we are talking about the possibilities we have as consumers to introduce distortions to the original signal. This means our power source and playback equipment. Ideally, our noise floor is at least equivalent to the dynamic range of the source material. Today, our best source is 24 bit digital, which in theory, can offer a dynamic range of 144 dB. Today's better A/V equipment has over 100 dB of available range. We will go further into the electrical systems later.

The other system is our acoustic environment. This is also measured in dB, but converted from Sound Pressure Levels (SPL) (0 dB = 20 µPa) at different frequency octave band centers, and then applied to curves known as the Noise Criteria (NC) curves. These curves take into account human perception and the fact that our hearing mechanism has different thresholds of sensitivity at different frequencies (see example Figure 1.). We measure the noise floor with the HVAC on and all equipment running and then often compare it to the noise floor with everything off. Depending on how the measured noise curve positions onto the NC contours determines which single number value rating the environment is given. A typical private urban residence is NC 25-35. An excellent home theater would be NC 10-15. This will allow you to hear your eyes blink.

Noise is a two way street. If noise can

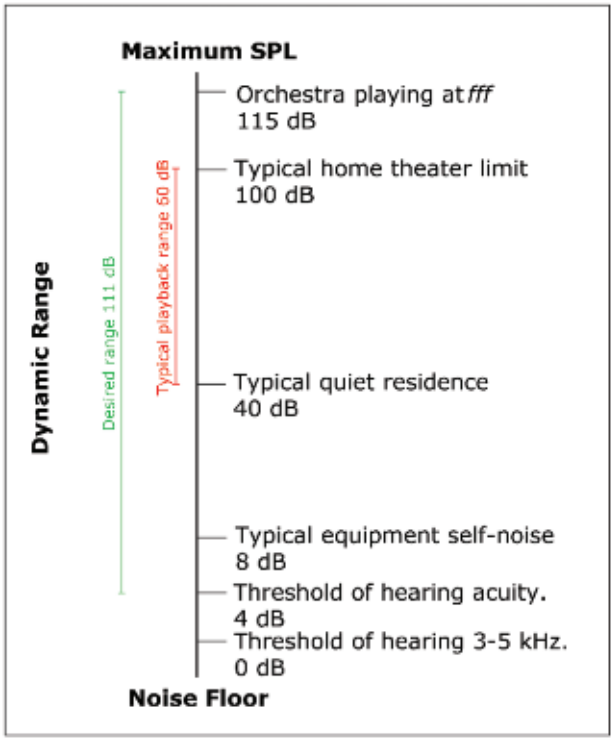

Figure 2. This chart suggests that the usable dynamic range for listening to live acoustic music can be 111 dB, and that typical residential electronic playback is only 60 dB.

get into the room, it can also get out. People who don't think about acoustics find that they can't use their theatre after the kids are in bed. People who don't think about acoustics find it hard to believe they are in outer space when they hear a car honk from outside. Noise distractions won't allow you to be fooled. In our multichannel acoustics lab, my mom shushed my daughter while watching "Swan Lake." She had temporarily believed that she was at the ballet. We all had a good laugh. Everyone's noise scenario is different. There are space constraints, budgetary, weight, material availability, etc., as well as the actual noise energies. There is no "one size fits all" to noise control. To design the appropriate solution requires knowledge of materials, engineering and computer modeling. Noise control requires a system approach of various disciplines that include blocking, isolating, absorbing and/or breaking noise and vibrations. These approaches are implemented along the sound path i.e., the source, the pathway and/or the receiver. It takes an acoustic specialist to know or discover how sound and vibrations are being transmitted and how to best mitigate them. It takes acoustic engineering to design an HVAC system that will be sufficiently comfortable and sufficiently quiet. Appropriate materials, air velocity, duct size, number and location of bends, etc. all must work together to achieve the goal. That goal is to hear the original signal. Anything that is added or subtracted is distortion and will take away from the experience intended by the artists. When you're watching a movie, you don't want to see or hear the room.

White Level (Peak Output)

How loud can we go? There are several limiting factors to consider.

1. ELECTRONIC DISTORTION: How loud will the equipment go before distortion?

This can be verified via a good subjective ear, or with instrumentation via a volt/ohm meter and/or oscilloscope. Essentially, we need to be sure that the electronic equipment is operating well within its proper operating range without
clipping, or going into oscillation, etc. In addition, the loudspeakers must be able to mechanically handle the power delivered without being over-driven.

2. ARTICULATION: Is the loudness compared to the room's reverberation times sufficient?

This has to do with the build up of sound within the room. A highly reverberant room will quickly fill with sound bouncing around adding to the direct sound from the speakers, making intelligibility and dynamics poor. Resonances can also play into the room after the original event and plague articulation. Think of a tiled shower stall and how easily it becomes very loud and resonant, and how low level sounds become inaudible.

3. SPL: Will it hurt?

By all means be careful with how loud you play back. People who have not applied good acoustics and/or calibration, are often turning it up to hear dialogue and then down for loud passages, which is not only annoying, but could cause equipment damage to a weak system. Other people simply play back too loud all together. I like to listen at fairly realistic levels, meaning acoustic instruments at real world levels and movies at the calibrated 75 dB reference level. I find that I'll listen to The Beatles around 95 dB SPL. At this level, I should be safe for about 4 hours per day. Playing it at 115 dB SPL, you're only safe for 15 minutes. If it's uncomfortable, it's probably not safe. Note that your ears can accommodate gradual volume increases fairly well, like slowly cooking a live frog to death. If your ears are ringing afterwards, they're probably overcooked.

Dynamic range is different than signal-to-noise ratio. Dynamic range is the possible dB values a waveform can have, dependent on the type of media used, while S/N is the level difference between the loudest component producible by the electronic device and it's noise floor. Each noise level in the electro-acoustical system sums to establish your noise floor. The maximum loudness level is determined by the maximum electronic, mechanical or acoustical level attained before distortion occurs. The space between these two points establishes your systems available dynamic range, or resolution factor (See Figure 2). To put this in perspective, you can gain 20 to 40 dB of dynamic range if you *acoustically* lower the noise floor. You can also make a 3 dB improvement every time you double your systems power handling capabilities. The later quickly causes your ears to bleed.

In this installment we touched on noise control and how it relates to sound quality. It is the foundation needed for quality sound to exist, and it may also be required so that others are not disturbed. We also suggested that without acoustic noise control you are likely missing out on many aspects of the recording that are very rewarding, primarily low-level details, dynamic range and no distractions. A quality listening environment can be a truly wonderful retreat. It can transport you to other worlds and adventures in a very persuasive, believable manner. In the following installments, we will focus more on sound quality issues and how they affect your experience.
Warning: As you apply acoustics into your life, it will likely increase your heart rate and blood pressure. WSR